# FIELD DEMONSTRATION OF ENHANCED SORBENT INJECTION FOR MERCURY CONTROL

## QUARTERLY TECHNICAL PROGRESS REPORT

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# Disclaimer

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| | |
|---|---|
| AC | activated carbon |
| BOP | balance of plant |
| CMM | Continuous mercury measurement |
| DJ3 | PacifiCorp's Dave Johnston Unit 3 |
| DOE | U.S. Department of Energy |
| EERC | Energy and Environmental Research Center |
| ESP | electrostatic precipitator |
| NETL | National Energy Technology Laboratory |
| NDIC | North Dakota Industrial Commission |
| PRB | Powder River Basin |
| SCA | specific collection area |

## Executive Summary

ALSTOM Power Inc., Power Plant Laboratories (ALSTOM-PPL) is currently carrying out a consortium-based, DOE-NETL program to demonstrate Mer-Cure$^{TM}$ technology, ALSTOM-PPL's novel and oxidation-based mercury control technology in coal-fired boilers. In the program, ALSTOM-PPL teams up with the University of North Dakota – Energy and Environmental Research Center (EERC), PacifiCorp, Basin Electric Power Cooperative (Basin Electric), Reliant Energy, North Dakota Industrial Commission (NDIC), and Minnkota Power.

The full-scale demonstration program consists of three seven-week long test campaigns in three independent host sites firing a wide range of coal ranks. These host sites include PacifiCorp's 240-$MW_e$ Dave Johnston Unit 3 burning a Powder River Basin (PRB) coal, Basin Electric's 220-$MW_e$ Leland Olds Unit 1 burning a North Dakota lignite, and Reliant Energy's 170-$MW_e$ Portland Unit 1 burning an Eastern bituminous coal. These boilers are all equipped with an electrostatic precipitator (ESP).

In Mer-Cure$^{TM}$ technology, a small amount of sorbent (Mer-Clean$^{TM}$) is injected into a flue gas stream environment where the gaseous elemental mercury oxidation and removal is favorable. The sorbents are prepared with chemical additives that promote oxidation and capture of elemental mercury. The Mer-Cure$^{TM}$ mercury control technology offers a great opportunity for utility companies to control mercury in the most cost-effective manner while minimizing any balance-of-plant impact.

ALSTOM-PPL has made significant accomplishments for the first of the three demonstration campaigns of the Mer-Cure$^{TM}$ system. The accomplishments during the period are summarized below:

- Held a site kick-off meeting at PacifiCorp's Dave Johnston Station;
- Completed fabrication of a mobile Mer-Cure$^{TM}$ system which can be utilized for all three test sites of the program;
- Completed site preparation including injection port installation and sampling ports during PacifiCorp's May outage;
- Shipped the mobile Mer-Cure$^{TM}$ system to the first of the three test sites, i.e., PacifiCorp's Dave Johnston Station;
- Assembled Mer-Cure$^{TM}$ system and performed its shakedown for PacifiCorp test campaign;
- Completed baseline measurements of mercury at Dave Johnston Station; and
- Signed Host Site Agreement with Reliant Energy, the third host site.

In the next performance period, ALSTOM-PPL will complete PacifiCorp test campaign and start preparation for Basin Electric test campaign.

## INTRODUCTION

The overall objective of the DOE/NETL-sponsored project is to perform full-scale demonstration of Mer-Cure$^{TM}$ technology in three coal-fired boilers burning coals of various ranks. These host sites include PacifiCorp's 240-$MW_e$ Dave Johnston Unit 3 (DJ3) burning a PRB coal, Basin Electric's 220-$MW_e$ Leland Olds Unit 1 (LO1) burning a North Dakota lignite, and Reliant Energy's 170-$MW_e$ Portland Unit 1 burning an Eastern bituminous coal. These boilers are all equipped with an ESP (Table 1).

In the program, ALSTOM-PPL will demonstrate that greater than 70% of gaseous mercury in the flue gas can be captured by injection of enhanced sorbent at a feed rate significantly lower than required by standard activated carbon. ALSTOM-PPL will also collect performance data that can be used to accelerate commercialization of our mercury control technology.

Mer-Cure$^{TM}$ technology applied to coal-fired power generation has the potential to be a cost-effective mercury control technology for the entire range of coals (bituminous, sub-bituminous, and lignite) and, in particular, the more challenging coals (for example, PRB and lignite coal). This control technology has low-capital costs (less than \$5/$kW_e$). It also requires a very small amount of additives for treatment, which results in low operating costs (0.5-0.75 mills/kWh) and minimal balance-of-plant (BOP) impact. As the technology is based on oxidation and adsorption of mercury, it is also applicable to all air pollution control configurations including wet scrubber and spray dryer-ESP/baghouse units. The main focus of the project, however, is coal-fired boilers with a cold-side ESP as the particulate control device, which represents 70% of the installed base in the United States.

The test program includes installation of equipment for the mercury control system, its operation under various firing conditions and measurement of elemental and oxidized mercury concentrations in the flue gas. The testing includes a one-week baseline mercury measurement and two weeks of parametric testing, followed by a four-week long-term testing. During the two-week parametric testing, the ALSTOM-PPL mercury control system will be operated with sorbents of several formulations at different sorbent injection rates to determine mercury oxidation and removal efficiencies. The optimum sorbent formulations and injection rates will be selected for the four-week testing to evaluate its long-term performance.

The EERC participates in the program by providing mercury measurement expertise. Continuous mercury measurement (CMM) will be carried out throughout the test period by installing CMM monitors before the injection location and after the ESP to provide both elemental and oxidized mercury concentrations in the stack gas. Ontario Hydro method will also be employed for some of the key test conditions to verify CMM data, to obtain mercury concentration and speciation measurements at ESP, and to ensure QA and QC of the measurements.

Table 1. Host site, coal and emission data for the field demonstration program

| | PacifiCorp | Basin Electric | Reliant Energy |
|---|---|---|---|
| Unit | Dave Johnston 3 | Leland Olds 1 | Portland 1 |
| Capacity ($MW_e$ Gross) | 240 | 220 | 172 |
| Operation | Base-loaded | Base-loaded | Cycling |
| $NO_x$ and $SO_2$ control | No low-$NO_x$<br>Low sulfur coal | No low $NO_x$<br>Low sulfur coal | Low-$NO_x$ - LNCFS<br>No sulfur control |
| Air Heater | Two Ljungstrom | Ljungstrom + Tubular | Ljungstrom |
| Particulate control (SCA in $ft^2$/kacfm) | CS-ESP<br>(629) | CS-ESP<br>(320) | CS-ESP<br>(284) |
| Ash utilization | Sold for mine reclamation | Disposal | Disposal |
| Coal | Wyodak (PRB) | ND lignite | Bailey mine Pittsburgh seam coal |
| Higher Heating Value As-received(Btu/lb) | 8,060 | Lignite<br>6617 | 12,800 – 13,100 |
| S in coal (%) | 0.94 | 0.63 | 2-2.5% |
| Ash % | 10.09 | 9.86 | 6-8% |
| Cl in coal (ppmwd)-dry | <50 | ~ 20 | ~1,500 |
| | PRB coal data | Lignite coal data | Bituminous coal data |
| Hg in coal (ppmwd)-dry | 0.071 | 0.057-0.099 | 0.1-0.16 |
| As-fired Hg level from Coal ($\mu g/Nm^3$) | 7-9 | 6-10 | 10-16 |
| Inlet Hg ($\mu g/Nm^3$) | | T-7.9; PM-2.0; Ox-0.1; El-5.8- March ’03 | T-9.1; PM-0.9; Ox-7.4; El-0.8$^+$ |
| Uncontrolled Hg Emission Stack ($Hg^T$, $Hg^p$, $Hg^{ox}$, $Hg^{el}$) ($\mu g/Nm^3$) | T: 5.55-8.71<br>PM: 0.01-0.04<br>El: 2.4-4.35<br>Ox: 3.1-4.35 | T-7.8; PM-0.0; Ox-1.4; El-6.4- March ’03 | T-7.5; PM-0.0003; Ox-5.2; El-2.3$^+$<br>after ESP, before scrubber |
| Removal Efficiency | | 12-25% (ICR data) | 36% for bituminous coals with CS-ESP |
| Carbon-in-ash | | < 0.2% | 10-12% |
| Flue gas temp (ESP Inlet) | 330-360°F | 375°F | 277°F – full load |

$^+$Data from 150 MWe AES-Cayuga (CE-LNCFS III with an ESP/scrubber) burning similar Pittsburgh seam coal with 2.3% S, 0.09% Cl and 0.1 ppmd Hg

Table 2. Scheduled outages of the three host sites

| Host sites | Scheduled outage | Demo period |
|---|---|---|
| PacifiCorp Dave Johnston 3 | Apr 30 – May 31, 2005 | mid June – mid Aug, 2005 |
| Basin Electric Leland Olds 1 | June, 2005 | early Sept – early Nov, 2005 |
| Reliant Portland 1 | Mar 26 – May 2, 2005 | mid Mar – mid May, 2006 |

## EXPERIMENTAL

The four major tasks being performed for the on-going demonstration project are:

Task 1. Design, Engineering and Fabrication of the Mer-Cure$^{TM}$ System
Task 2A. Field Demonstration at PacifiCorp's Dave Johnston Unit 3
Task 3. Technology Transfer
Task 4. Program Management and Reporting.

During the performance period, a site kick-off meeting was held at PacifiCorp's Dave Johnston Unit 3. Task 1 has been completed in time for the scheduled testing. Also, part of the Task 2, i.e., delivery, assembly and shakedown of the Mer-Cure$^{TM}$ System, as well as the baseline mercury measurement, has been carried out. Details of the project activities are described in this section.

### Task 1. Design, Engineering and Fabrication of Mer-Cure™ System

As discussed in the previous quarterly report, ALSTOM-PPL had decided to purchase, rather than lease, major components of the Mer-Cure$^{TM}$ System and to assemble a mobile unit that will be used for all three demonstration sites. This idea was proposed to DOE/NETL. In this quarter, ALSTOM has received approval from DOE/NETL. In the month of May, ALSTOM-PPL has completed design and fabrication of the mobile Mer-Cure™ system in time for the first test campaign.

The mobile Mer-Cure™ system completed is composed of three components mounted on a 48-foot trailer: a sorbent storage system, a sorbent processing/delivery system, and a sorbent distribution system (Figure 1). The sorbent storage system is a portable solid storage silo that comes in two pieces (each piece is 8 ft high), can be easily assembled, and requires a relatively small footprint. The sorbent storage system, when assembled, is capable of loading powdered material of up to three 900-lb super-sack bags at the same time and will allow uninterrupted

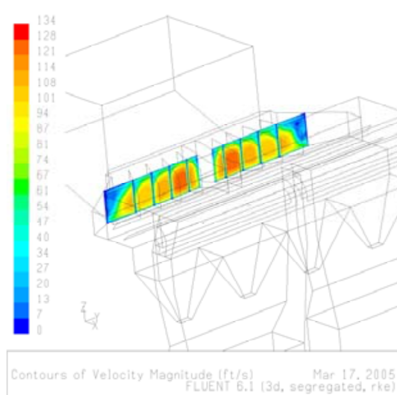

Figure 1. Mer-Cure™ system positioned on the east side of DJ3 boiler

operation for 24 hours at a typical injection rate. Due to height limitations of the trailer during transportation, the storage system is delivered unassembled. The top piece of the two-piece storage system is then attached to the base piece permanently mounted on the trailer at the test site before testing.

The sorbent processing/delivery system is a variable screw feeder for metering the sorbent and an eductor for its pneumatic transport to a processor, a processor that de-agglomerates sorbent particles, and a system for dry, compressed air for pneumatic transport. This system is mounted next to the storage system and completely connected to the other subsystems.

The sorbent distribution system is flexible hoses and interconnecting pipes, distribution manifolds and injection lances. The injection lances are a number of 1 ¼-inch pipe sections with multiple nozzles for even distribution throughout the duct cross-section at the injection location.

In preparation for the design of the site-specific portion of the Mer-Cure™ system, site visits were made to all three sites. During the visit, more detailed information was collected such as that on the injection location (e.g., duct dimensions, turning vane arrangement), workspace, sampling port locations, trailer placement, equipment placement and the availability of utilities at work locations. The injection lances for DJ3 have been designed based on computational fluid dynamics (CFD) studies. As shown in Figure 2, the flow distribution of flue gases at the injection location varies widely. Despite turning vanes at the transition ducts, most of the flue gas flow stays in the middle of the cross section (sections “d” and “g” of Figure 2). Also, some recirculation of flue gases is observed on both ends of the duct cross section (sections “a” and “j”




| | % | Normalized to lowest flow |
|---|---|---|
| a | 8.92% | 1.31 |
| b | 10.27% | 1.51 |
| c | 11.04% | 1.63 |
| d | 13.01% | 1.91 |
| e | 6.79% | 1.00 |
| f | 6.83% | 1.01 |
| g | 13.08% | 1.93 |
| h | 10.86% | 1.60 |
| I | 10.31% | 1.52 |
| j | 8.89% | 1.31 |

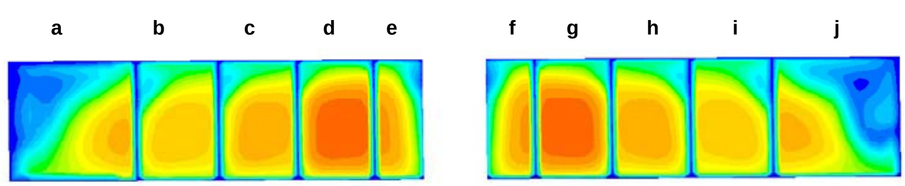



Figure 2. Flue gas flow distribution at the injection location of DJ3 boiler

of Figure 2). Based on the calculated flow distributions, the numbers of injection ports, injection lances and their nozzles have been determined. During the outage (month of May), PacifiCorp completed installation of the injection ports.

CFD studies similar to the ones discussed above have been completed for the injection locations of the other two test sites as well. In order to verify some of the results, velocity measurements were carried out. These studies allowed design of injection lances that could be used for multiple sites. These study results will be reported in detail in the future topical reports describing corresponding test campaigns.

Control and data acquisition systems for the mobile Mer-Cure™ system were designed and assembled as part of the system preparation. The control system allows remote monitoring of operating conditions of the three subsystems of Mer-Cure™ system. It also automatically shuts down the Mer-Cure™ system in case of boiler emergency or internal system failure. The control system is designed to receive load signals from the boiler and to vary sorbent injection rate as a function of boiler load for peaking units such as Reliant Energy's Portland Unit 1. The data acquisition system stores system operating data such as injection rates, pressure levels of various sections of the sorbent delivery, processing and injections systems, and temperatures.

During May outage, PacifiCorp completed site preparation in time for June testing. This included installation of sorbent injection ports and sampling ports, relocation of an office trailer, preparation of electric utilities for ALSTOM's Mer-Cure™ system and EERC's measurement systems, and preparation of sorbent storage and staging area.

**Task 2A. Field Demonstration for PacifiCorp Campaign**

In the month of June, the completed mobile Mer-Cure™ system was shipped to PacifiCorp. The Mer-Cure™ system was placed on the east side of the DJ3 boiler. The sorbent storage and delivery system was assembled at the site; the sorbent processing system was placed close to the sorbent injection system and was connected to the storage system by 4-inch flexible hoses. The sorbent distribution system was installed at the sorbent injection location as shown in Figure 3, and connected to the delivery system by 4-inch flexible hoses. All of the systems were secured to the boiler structure.

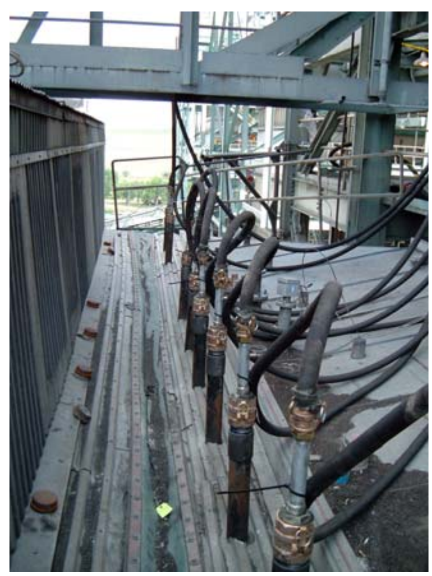


Figure 3. Sorbent injection system

Figure 4 shows the Mer-Cure™ system after installation. Shakedown of the assembled system was then carried out after baseline mercury measurements.

While the Mer-Cure™ system was being assembled, EERC installed their PS Analytical

Figure 4. Mer-Cure™ system positioned on the east side of DJ3 boiler

mercury measurement systems at the air heater inlet (east side) and stack and performed baseline measurements of vapor phase mercury. The PS Analytical systems were equipped with an inertial separation probe, which allows sampling of flyash-free flue gas.

In the next quarter, the

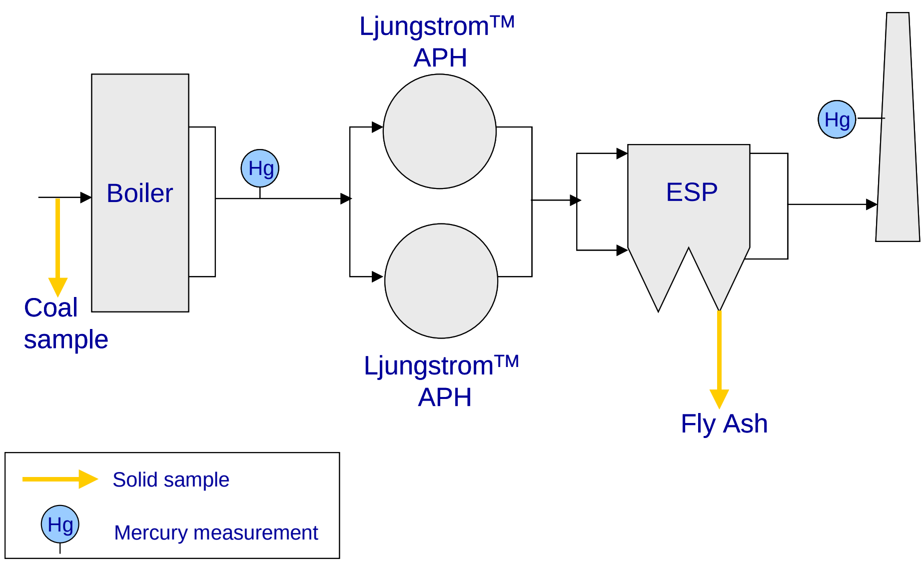



Figure 5. Schematic diagram of sampling locations at DJ3

parametric testing will be carried out with several treated sorbents at a range of injection rates. Long-term testing will then follow for four weeks under a couple of optimized testing conditions. During the parametric and long-term testing, various plant data will be collected to evaluate the performance of Mer-Cure™ system. The mercury levels will be monitored at the air heater inlet and the stack. Coal samples will be collected from mills; ash samples will be collected from ESP hoppers and the ash silo. Gas analysis data will be obtained from the plant data collection system. ESP operating parameters will be also monitored.

## Task 3. Technology Transfer

The project status will be reported in the upcoming DOE/NETL Contractors' meeting in Pittsburgh, PA. A Power Point presentation will be made available through DOE/NETL on their website.

## Task 4. Project Management and Reporting

During the reporting period, ALSTOM-PPL had a project kick-off meeting with PacifiCorp at Dave Johnston Station. During the kick-off meeting, the work breakdown was discussed in detail in preparation for the PacifiCorp test campaign. Weekly teleconferences were held among team members in order to coordinate various aspects of the test campaign.

Basin Electric has been given material and instructions for injection port installation. Ports will be installed before completion of PacifiCorp test campaign. We also have completed Host Site Agreement with Reliant Energy.

## RESULTS AND DISCUSSION

During the reporting period, the baseline mercury levels were measured both at the air heater inlet and the stack. Figure 6 shows typical variations of speciated mercury levels at the measurement locations. These measured mercury levels are uncorrected vapor phase mercury levels.

During measurement, the economizer outlet excess oxygen level was maintained around 3% and the load of the boiler was kept at around 225 $MW_e$. The total vapor phase mercury level at the air heater inlet varied between 10 and 12 $\mu g/m^3$, while that at the stack was between 9 and 11 $\mu g/m^3$. Up to 50% of the stack mercury is elemental. This elemental mercury level is lower than expected. The skewed speciation may be due to the stainless steel surface of the inertial separation probe. Ontario Hydro measurements have been carried out to substantiate the speciation and will be reported in the next quarter.

According to the CMM data, the inherent mercury capture between the two sampling locations at DJ3 during this measurement was between 0 and 20%.

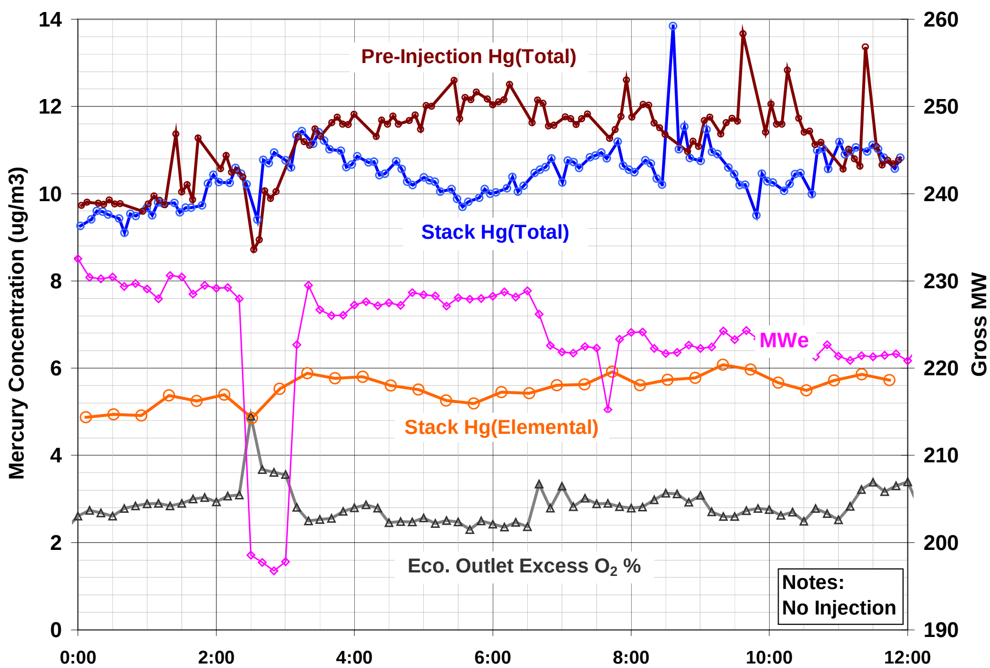



Figure 6. Baseline mercury measurement results

## MILESTONES AND SCHEDULE

PacifiCorp test campaign is being performed as scheduled. The first milestone of the program is completion of setting up our Mer-Cure™ system in time for eight week testing. This milestone has been reached. The next milestone is delivery of the site report by the end of January 2006.

Parametric testing and long-term testing at DJ3 are currently underway. Basin Electric testing is also being prepared. As soon as the PacifiCorp testing is completed, the mobile Mer-Cure™ system will be dissembled and shipped to Basin Electric's Leland Olds Station.

Table 3. Schedule for Mer-Cure™ demonstration

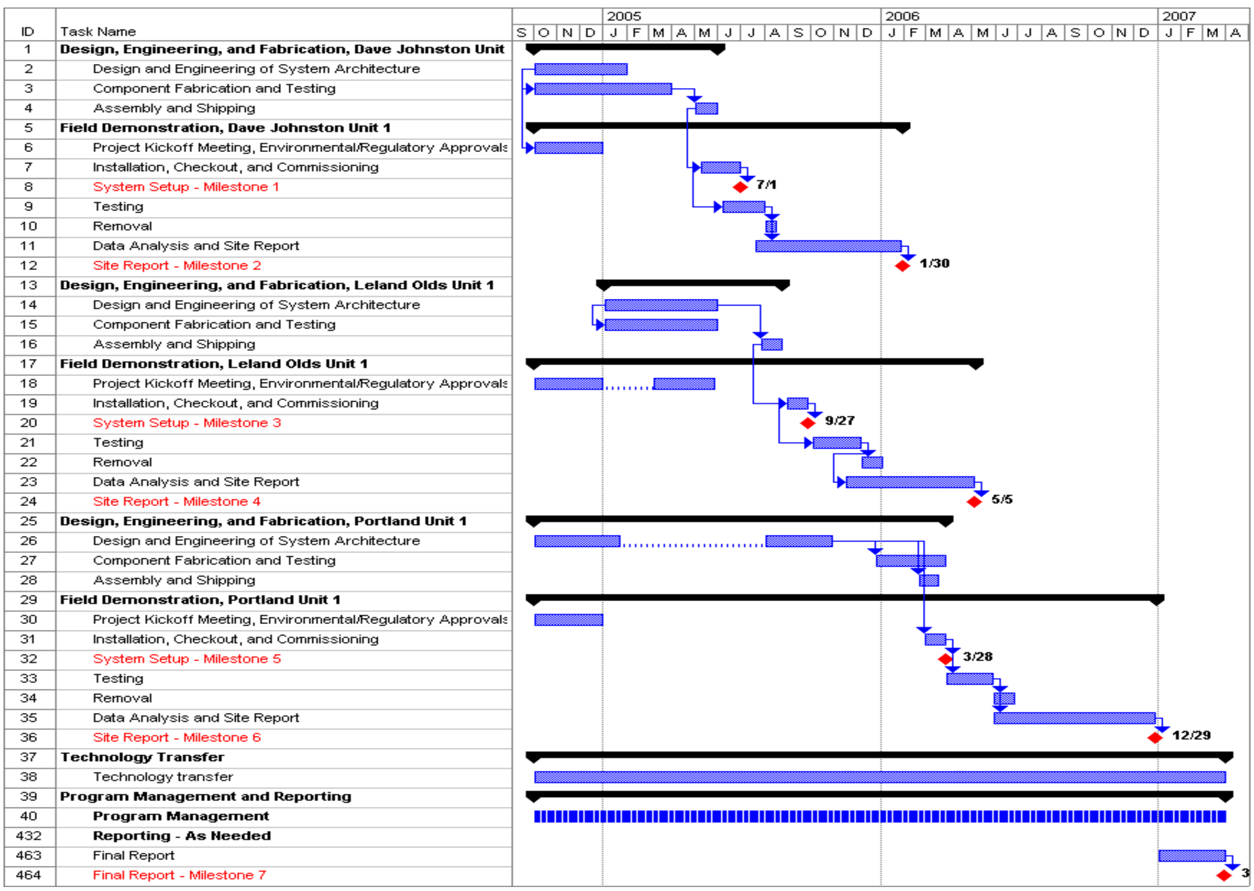


Table 4. Milestones and Deliverables

| Milestone/ Deliverable | Original | Revised | Actual |
|---|---|---|---|
| 1. System setup – Dave Johnston (PacifiCorp) | 7/1/05 | | 6/18/05 |
| 2. Site Report – Dave Johnston (PacifiCorp) | 1/30/06 | | |
| 3. System setup – Leland Olds (Basin Electric) | 9/27/05 | | |
| 4. Site Report – Leland Olds (Basin Electric) | 5/5/06 | | |
| 5. System setup – Portland (Reliant) | 3/28/06 | | |
| 6. Site Report – Portland (Reliant) | 12/29/06 | | |
| 7. Final Report | 3/30/07 | | |